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## **COGSCI APPLICATIONS**

**Northwestern University**

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## **STINFO FINAL REPORT**

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AFRL-IF-RS-TR-2005-170 has been reviewed and is approved for publication

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<b>13. ABSTRACT (Maximum 200 Words)</b> The purpose of this effort was to provide support for the following conference and workshop which were held during August 2004 in Chicago IL:  The 26 <sup>th</sup> Annual Conference of the Cognitive Science Society. This conference is the premier venue for reporting current work in Cognitive Science. This conference is the primary meeting where new results on analogical reasoning and learning are reported. More information can be found at <a href="http://www.cogsci.northwestern.edu/cogsci2004">http://www.cogsci.northwestern.edu/cogsci2004</a> .  The 18 <sup>th</sup> International Workshop on Qualitative Reasoning. This workshop is the premier venue for reporting current work in qualitative reasoning. For example, results on human-like spatial reasoning, reasoning about complex devices, and creating intuitive models of complex non-linear dynamic systems of strong interest are reported there. More information can be found at <a href="http://www.qrg.northwestern.edu/gr04">http://www.qrg.northwestern.edu/gr04</a> .				
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## Introduction

The purpose of this funding was to provide support for two meetings:

- The 26th Annual Conference of the Cognitive Science Society. This meeting is the premier venue for reporting current work in Cognitive Science. For example, it is the primary meeting where new results on analogical reasoning and learning are reported. More information can be found at <http://www.cogsci.northwestern.edu/cogsci2004>.
- The 18<sup>th</sup> International Workshop on Qualitative Reasoning. This meeting is the premier venue for reporting current work in qualitative reasoning. For example, results on human-like spatial reasoning, reasoning about complex devices, and creating intuitive models of complex non-linear dynamic systems of strong interest to DARPA are reported there. More information can be found at <http://www.qrg.northwestern.edu/qrg04>.

Historically DARPA has valued and supported the development of the field of cognitive science in general and qualitative reasoning in particular. The interdisciplinary nature of cognitive science has provided a venue for researchers from computer science, psychology, neuroscience, anthropology, education, and philosophy to transcend their disciplinary boundaries and develop the leading edge theories and products valued by DARPA. Examples include research on qualitative reasoning, analogical reasoning, and augmented cognition. Indeed, the focus on the newly reconstituted IPTO office on Cognitive Systems indicates the depth of commitment to the idea that we must create information systems that are more like people, systems that know what they are doing, that can communicate and collaborate with human partners, and can reason and learn while operating for months and years at a time. Cognitive Science provides valuable clues about how this can be accomplished, by providing scientific results and insights based on humans (and sometimes other species).

By supporting these conferences, we gained a pipeline into a community of scientists and scholars that could provide valuable insights that will be useful for future DARPA programs and systems.

The funds were spent as budgeted, and the financial reports have already been submitted with full details. The proceedings are available on-line at the following locations:

Cognitive Science Meeting:

<http://www.cogsci.northwestern.edu/cogsci2004/>

Qualitative Reasoning Workshop:

<http://www.qrg.northwestern.edu/qrg04/>

These sites have papers broken down into individual files, since that maximizes exposure to search engines such as Google. These are the public sites. For government purposes, single files of the proceedings may be found at <http://www.cs.northwestern.edu/~forbus>, specifically,

[http://www.cs.northwestern.edu/~forbus/Meetings\\_04/CogSci04\\_Proceedings\\_sans\\_front\\_matter.pdf](http://www.cs.northwestern.edu/~forbus/Meetings_04/CogSci04_Proceedings_sans_front_matter.pdf)

[http://www.cs.northwestern.edu/~forbus/Meetings\\_04/CogSci04\\_Front\\_matter.pdf](http://www.cs.northwestern.edu/~forbus/Meetings_04/CogSci04_Front_matter.pdf)  
[http://www.cs.northwestern.edu/QR04\\_Proceedings.pdf](http://www.cs.northwestern.edu/QR04_Proceedings.pdf)

The rest of this report provides an assessment of the meetings.

## **Assessment**

It is interesting to examine some of the work presented at these meetings with an eye towards potential new opportunities for DARPA and government research and development more generally. In this section I will describe some of the things that I found especially interesting from this perspective. These opinions are my own, and not those of the Cognitive Science Society, the US Government, nor should they be taken as representing the consensus of either of the research communities involved.

### ***International Workshop on Qualitative Reasoning***

Qualitative reasoning research has often focused on engineering applications. This has led to significant real-world benefits, e.g., the use of model-based reasoning during design (now done by Ford worldwide for automobile electrical systems, with other car companies rumored to be moving in this direction as well). Some excellent work continues in this vein (cf. the papers by Bell & Snooke, Struss, and Ramamoorthy & Kuipers). However, there is now a healthy broadening of what is being explored, leading to some intriguing new research areas.

- Using qualitative modeling for education. This is rapidly becoming a new major strand in the community, with 6 papers out of 31 involving education this year. Qualitative models are designed to be close to human mental models of physical systems, so it is exciting to see this potential start to become realized.
- Qualitative spatial reasoning remains a strong thread of research, with four papers ranging from basic qualitative shape matching to use of qualitative spatial techniques to analyze numerical data.
- The use of qualitative reasoning for modeling ecosystems. (3 out of 31) Ecologists coming to the Workshop are skeptical of classical modeling techniques, arguing that they require more quantitative data than is available, provide a false sense of precision, and fail to highlight patterns of behavior that lead to insights. This is consistent with the arguments made earlier by researchers using QR for modeling nonlinear dynamical systems, who exploited qualitative representations of phase space for design and control, e.g., the work of Bradley, Zhao, and their collaborators.
- Some of novel uses of qualitative modeling are being explored, including robotics, virtual reality, natural language semantics, and using compositional modeling to create Bayes nets for crime scene investigation.

This expansion in the kinds of problems tackled is, I think, a very healthy sign. Qualitative representations may turn out to be a “sweet spot” in the space of formalisms

for decision problems and for reasoning about policies, as well as for modeling human reasoning about physical domains and engineering artifacts.

## ***Annual Meeting of the Cognitive Science Society***

This meeting is harder to summarize, since it was roughly an order of magnitude larger in terms of output (265 papers and posters, plus 150 member abstracts, versus 31 for QR04), and the number of attendees was roughly 800. Interestingly, after hovering at the 300 mark for many years, over the last three years we have seen an explosive growth in attendance. The center of gravity of the Society is still cognitive psychology, but there is still an intellectual breadth there that is hard to find in any other conference concerned with cognition.

We chose as the theme this year *higher-order cognition*. This theme was reflected in our choices for keynote talks and invited symposia, but to our surprise, the community responded quite strongly. We saw far more papers on language than we had expected, for example. The number of AI papers rose somewhat as well, through recruiting members of the AI community to serve on the Program Committee. Here are some highlights of the conference:

- John Anderson's Rumelhart Award talk. Anderson's work on the ACT-R model now stretches from hypotheses about specific functions of neural areas to modeling doing distracting tasks while driving a (simulated) car. The range and depth of his research programme and the results he has achieved are impressive. This award was well-deserved.
- The impact of culture on cognition is becoming a hot topic. As Doug Medin's keynote talk observed, most researchers use college students as their main source of participants in experiments, and assume that results generalize. There is now a growing body of evidence that they do not, and that conceptual structures and reasoning can vary quite significantly across cultures. A symposium on Language and Thought explored issues such as how causal verbs varied across languages, and what this might say about how causal events are represented non-linguistically.
- Gesture has become an important window for looking into cognition. Susan Goldin-Meadow's keynote talk described her research indicating that mismatches between what is said in speech and what is communicated via gestures can mislead students, when done by a teacher, and can be a sign of incipient conceptual change, when done by a student. (This is an important result to keep in mind when designing embodied conversational agents for interfaces.) A symposium organized by Greg Trafton of NRL brought together researchers from different disciplines to explore how gestures are used in spatial thinking.
- A symposium of qualitative reasoning researchers provided a bridge between the QR community and the Cognitive Science community. Creating such bridges via co-location was the reason why we took on organizing both meetings at the same time. There was considerable interest by cognitive science attendees in using QR

- techniques as formal representations for human mental models. We hope that this will lead to more joint research.
- The cognitive science community was made more aware of large-scale representational resources that have been developed for research purposes by a symposium that included George Miller (WordNet), Charles Fillmore (FrameNet), Doug Lenat (Cyc), and Martha Palmer (VerbNet). Lenat's description of ResearchCyc, and its near-term availability to the research community, caused considerable excitement. These resources, in the hands of the AI and Cognitive Science communities, could lead to an inflection point in the kind of research that can be carried out. It is impressive that these researchers have carried on, for over a decade in some cases, despite the current focus on short-range results in funding.

## Summary

Both meetings provided valuable scientific results, some of which directly bear on DARPA-related activities. We hope that the assessment above will excite the reader enough to delve into the proceedings, for there are many gems in them that are worth your time.